Sweet Sorghum: a good opportunity for producing bio-ethanol ?

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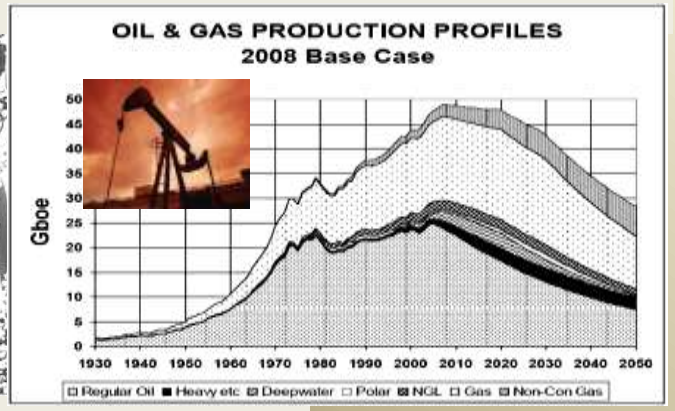
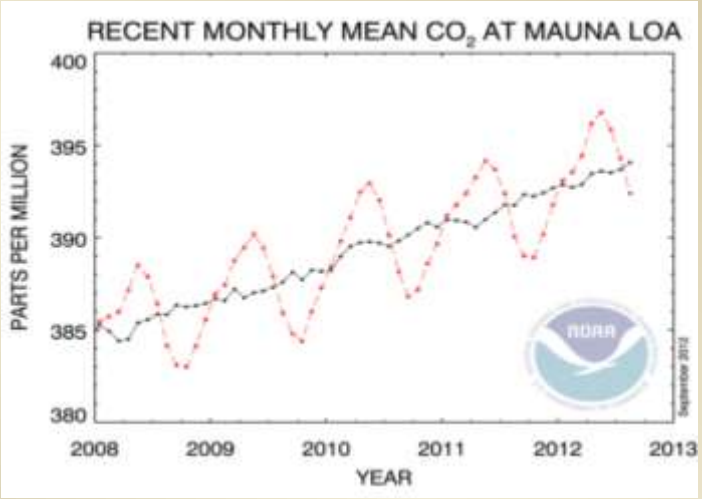
Context

Global oil production is rapidly approaching its peak



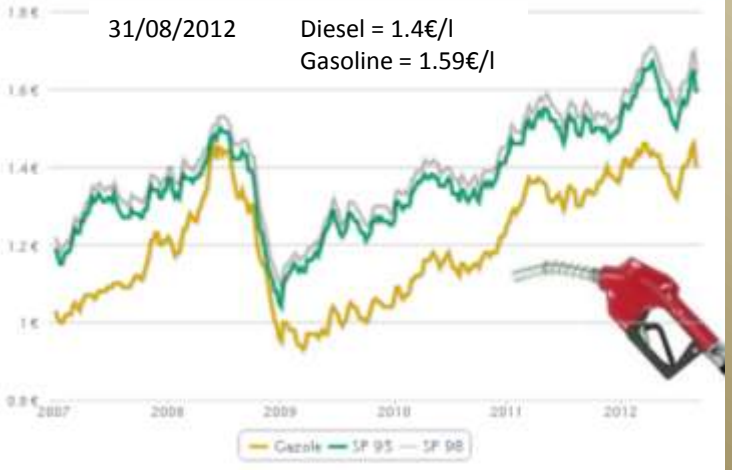
http://www.oildecline.com/



CO_2 atmospheric concentration in Aug. 2012 = **392.41 ppm**
http://www.esrl.noaa.gov

Evolution of price at the gas station

31/08/2012 Diesel = 1.4€/l
Gasoline = 1.59€/l



It is urgent to find alternative and sustainable energies

Biofuels or agrofuels, defined as solid, liquid or gas fuels derived from biomass, are today the only direct subsitute for oil on a significant scale particularly in the transport sector

Context

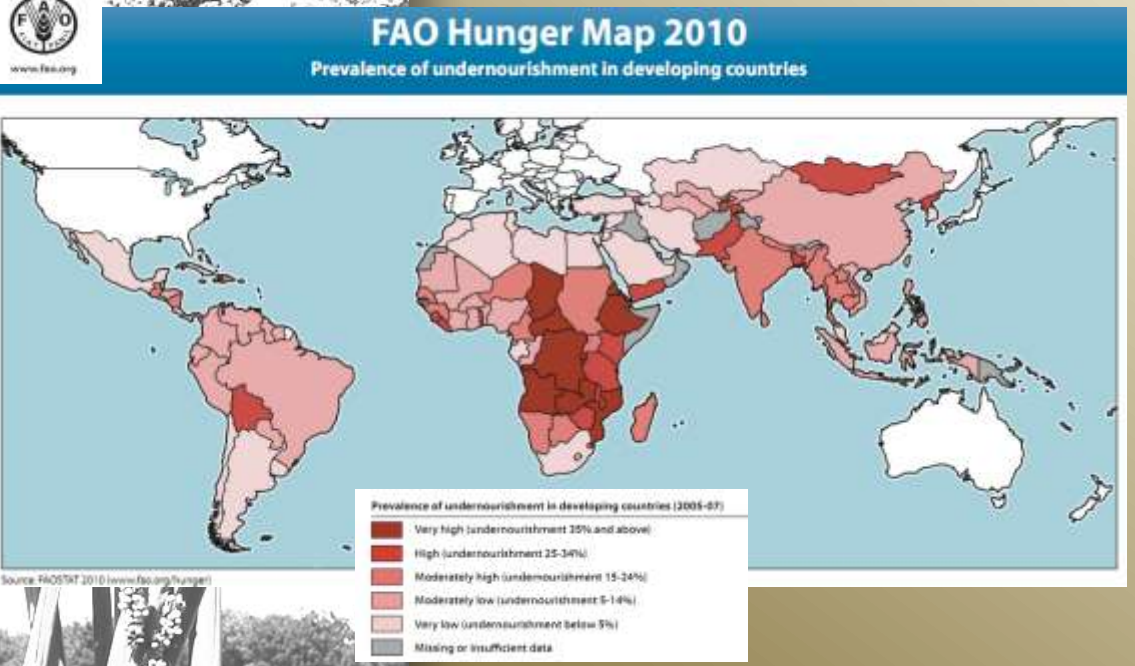
poorest countries will be lead to grow biofuel crops

Less arable surfaces available for food production

Increasing staple food world market prices
(good for producers, bad for urban consumers)

Instability of the staple food market

Increase of food insecurity



What are the main plants currently used ?

1G Bio-ethanol

2G Bio-ethanol

Bio diesel

Sorghum: few generalities

Grain sorghum = 5th cereal

World production (2010)

	2010 Production (million T)	Yield (Kg ha^{-1})
Maize	840	5195
Paddy rice	696	4368
Wheat	654	3009
Barley	124	2600
Sorgho	56	1361

(http://faostat.fao.org/)

Sorghum: few generalities

Main producers	2010 Production (millions of tonnes)	Area (1 000 ha)
USA	8,8	1 948
Mexico	6.9	1 768
India	6.7	7 790
Sudan	2.6	5 613
Nigeria	4.8	4 737
Éthiopia	3	1 619
Argentina	3,6	751
China	1.7	547

(http://faostat.fao.org/)

Sorghum: few generalities

Sorghum: few generalities

Verticilliflorum
(wild type)

Bicolor

Guinea

Caudatum

Durra

Kafir

Multi purposes crop

Biomass sorghum

Sorghum for silage

Grain sorghum

Broom corn sorghum

Sorghum for tinctures

Sweet sorghum

Combination of 2 essential traits:

1. **Production of grains**

2. **Accumulation of sugars in the stalks**

Why sorghum for producing 1G ethanol ?

Tropical zone

VS

Propagation
Cuttings seeds

Length of cycle
12-16 months 4-5 months

Water requirements
36 000 m3 / 8000 m3 (2 cycles)

Adaptation to dry zones
Irrigation yes

Adaptation to marginal soils
cane < < sorghum

Grain production
0 << up to 6T / ha (2 cycles)

Ethanol production (l ha-1)
6500 5600 (2 cycles)

Uses
Sugar, Fuel Food, Feed, Fuel

Energetic balance
sorghum ⇔ maize

Temperate zone

VS

Intrant needs
sorghum < < maize

Water requirement
1/3 less than maize

Water & Nitrogen Use Efficiency
sorghum > > maize

Adaptation to dry environments
sorghum > > maize

Adaptation to marginal soils
sorghum > > maize

Grain
sorghum << maize

Biomass
sorghum ⇔ maize
(25 to 40T DM ha-1)

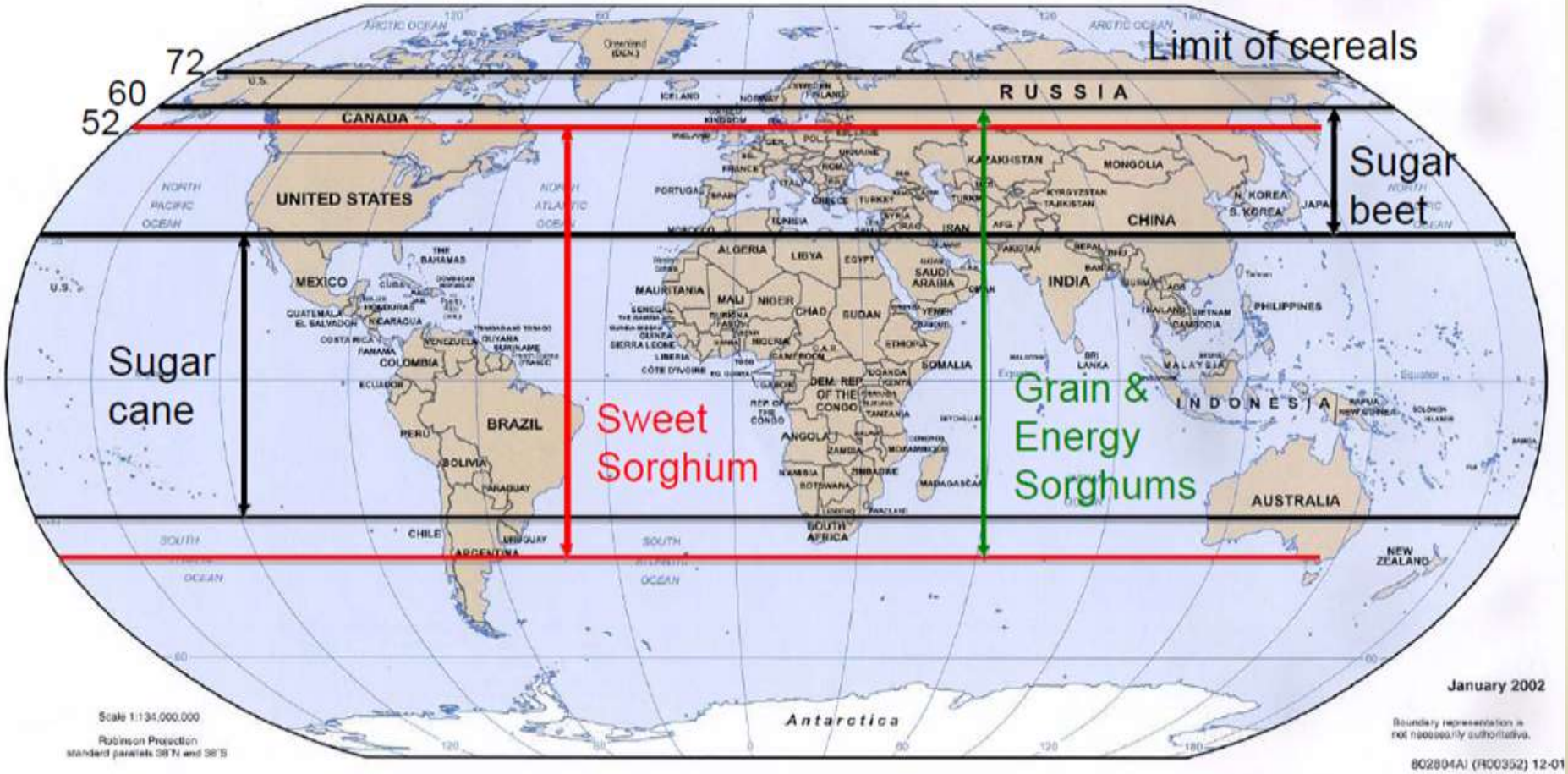
Energetic balance
sorghum > > maize

ADVANTAGE SORGHUM

Hudge potential of improvement and adaptation
Respect of environment
Development of rural zones
Low competition with food crop
Better sustainability of the production system

Why sorghum for producing ethanol ?

The Adaptability of Sorghum



What sorghum for what biofuel ?

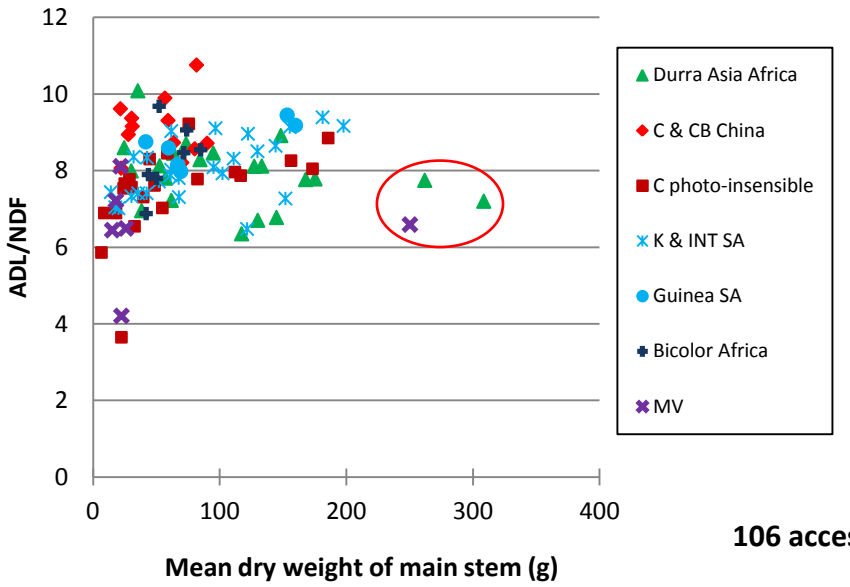
❶ **2nd generation EtOH** or **methane production :** a **biomass sorghum** with the following traits:

- ✓ **High biomass** production (30-40 TDM ha $^{-1}$) which means a plant height > 3.5-4m and a long cycle (4-5 months)
- ✓ good **tolerance to low temperature**
- ✓ a **photosensitivity** adapted to induce late flowering
- ✓ a **good quality** of the raw material which must be poor in lignin (*bmr* trait) to increase **digestibility** of the tissues
- ✓ a good **tolerance to lodging** (antagonistic with *bmr* trait)
- ✓ **tolerance to water deficit** / high water use efficiency

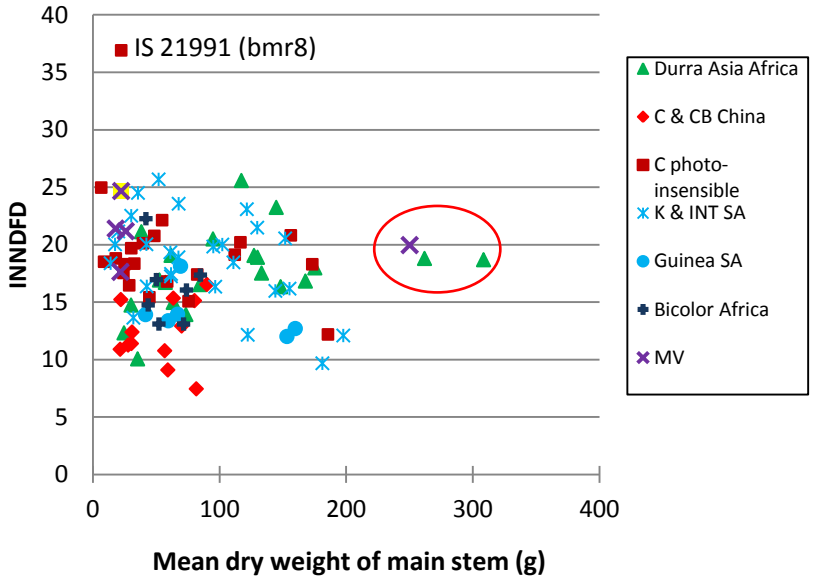
for that purpose, grain production is not essential

What sorghum for what biofuel ?

2nd generation EtOH or methane production : a biomass sorghum



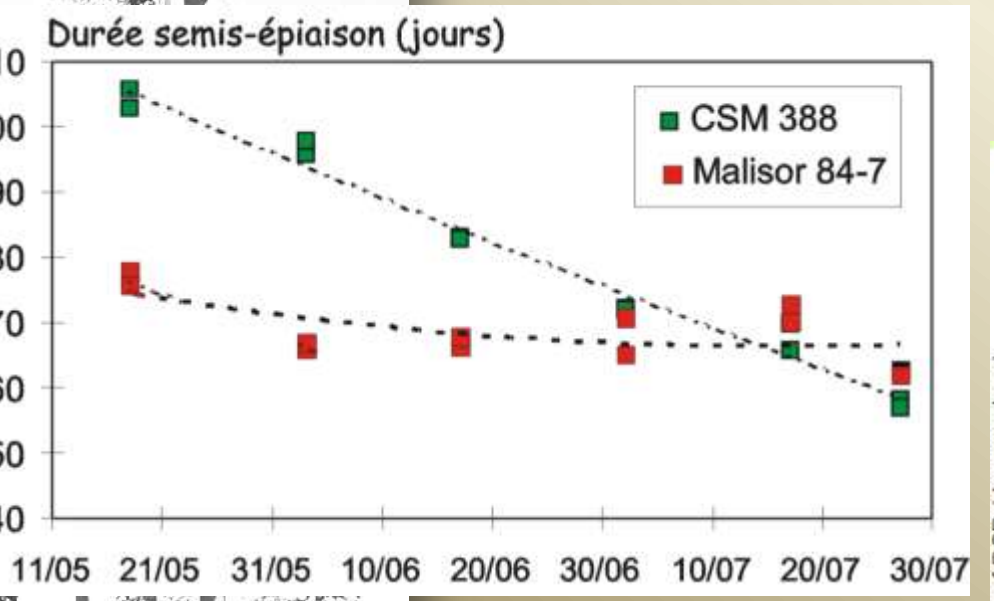
106 accessions



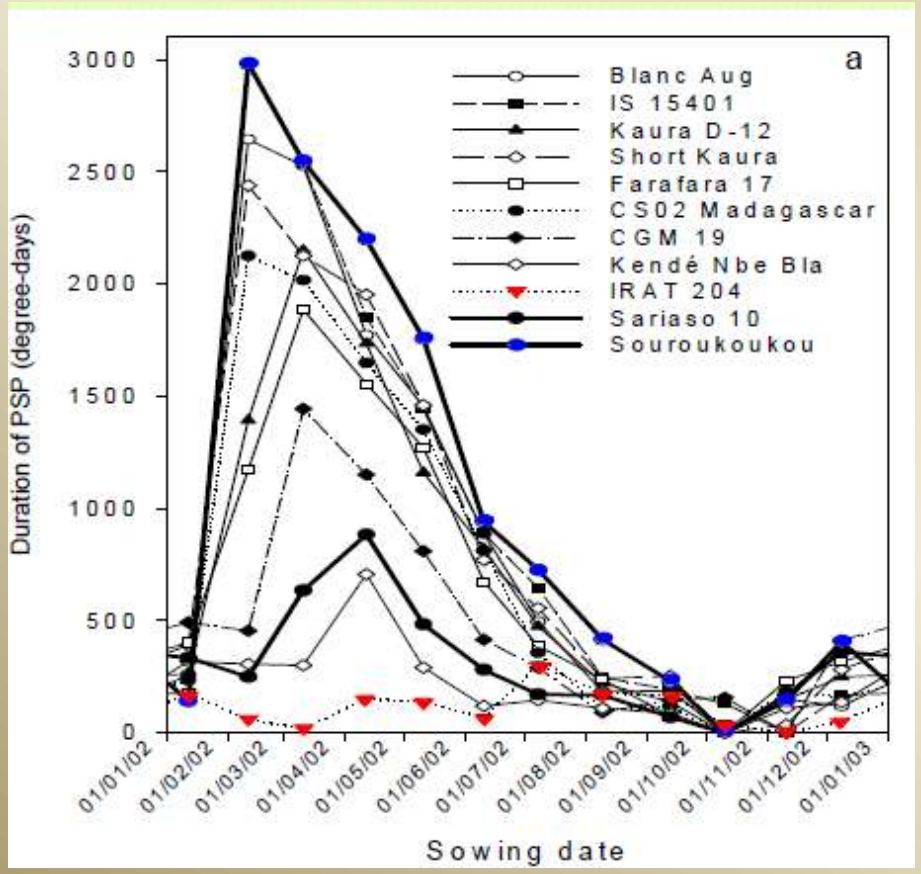
Possible combination of
+ high stalk biomass
+ low lignin content
+ good digestility of fibres

What sorghum for what biofuel ?

2nd generation EtOH or **methane production :** a **biomass sorghum**



Photosensitivity



What sorghum for what biofuel ?

2

1st generation EtOH and/or **cogeneration :** a **sweet sorghum** with the following traits:

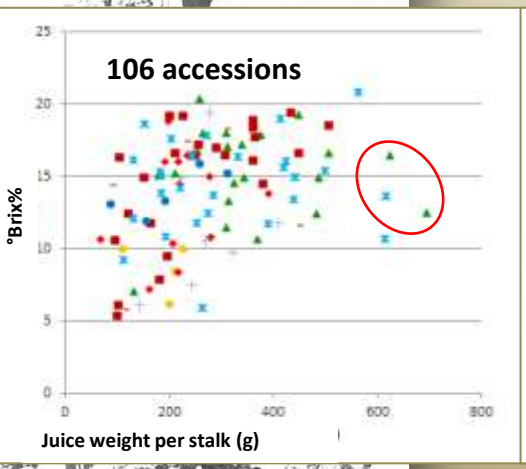
- ✓ **High biomass** production (30-40 TDM ha $^{-1}$) which means a plant height > 3.5-4m
- ✓ high accumulation of **soluble sugars in stalks**, °Brix% of 15 to 20 with 80% of saccharose
- ✓ **juicy** stalks
- ✓ high **energetic value of the bagasse** for cogeneration which means more fiber with lignin)
- ✓ adaptation to **marginal soils** (acidity, Al toxicity, P deficiency)
- ✓ **adaptation of crop cycles** (complementary with sugar cane)

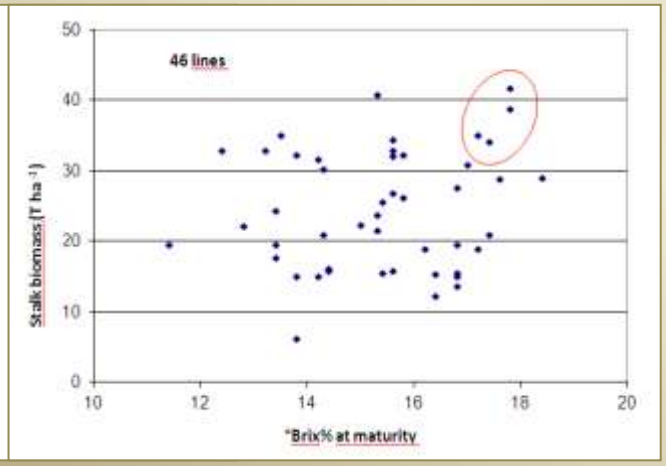
for that purpose, grain production is not wishable

What sorghum for what biofuel ?

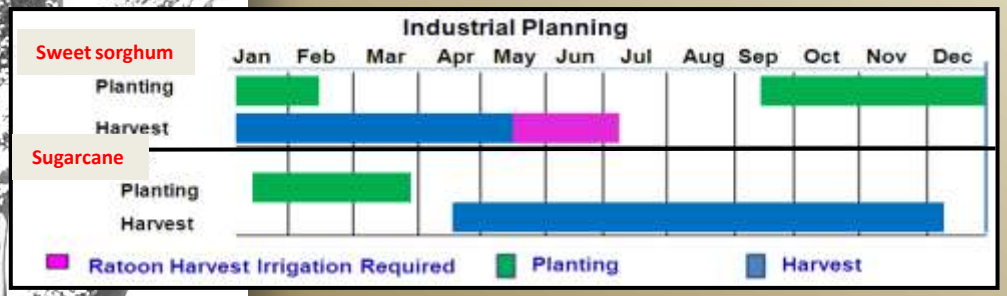
2

1st generation EtOH or cogeneration : a sweet sorghum (Brazil)





gene for tolerance to aluminum toxicity : ***Alt$_{SB}$***



Possible combination of
+ °Brix% with juice
+ °Brix% with stalk biomass
+ Al tolerance
+ complementarity sugar cane cycles (1.8 million ha)

What sorghum for what biofuel ?

3

1st generation EtOH combining **grain** and **fodder**: a sweet sorghum with the following traits:

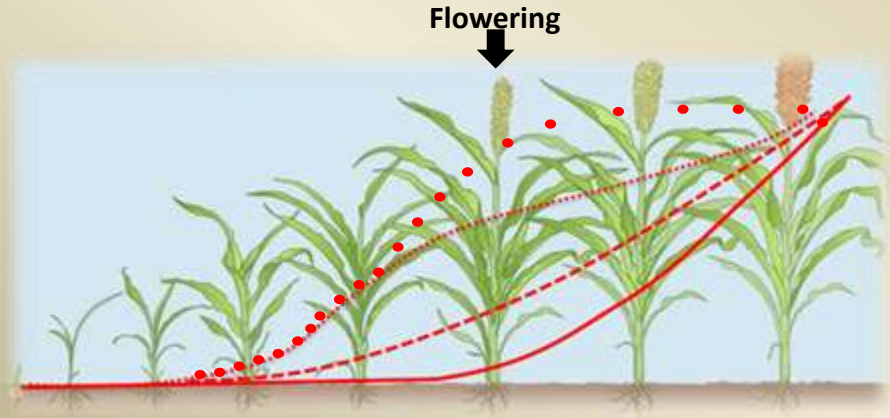
- ✓ **High biomass** production (20-30 TDM ha $^{-1}$) which means a plant height ± 3m and a long cycle (4-5 months)
- ✓ a mean production of **grain** (1.5 to 3 T ha $^{-1}$)
- ✓ high accumulation of **soluble sugars in stalks**, °Brix% of 15 to 20 with 80% of saccharose
- ✓ **juicy** stalks
- ✓ high value of the **bagasse as fodder** which means high digestibility (=*bmr* trait = low lignin content in bagasse)
- ✓ adaptation to **marginal soils** and **rainfall distribution** (stay green, adapted photosensitivity)

for that purpose, grain production is essential

Accumulation of sugar in staks

Processes of accumulation are not well characterized

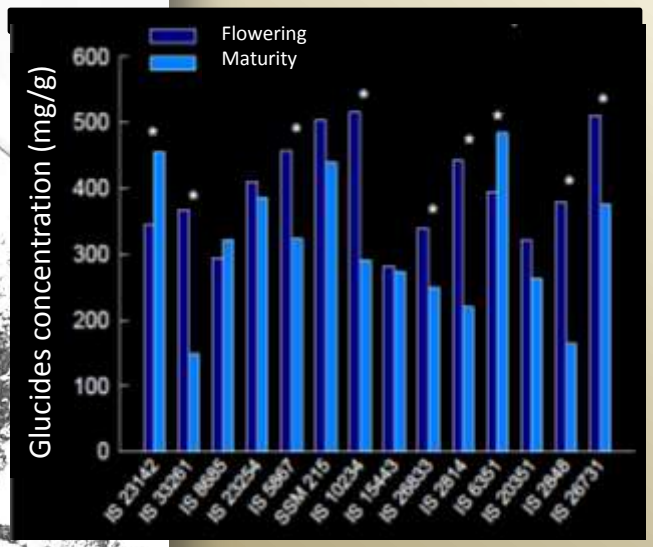
What is the right kinetic of sugar accumulation in stalks ?

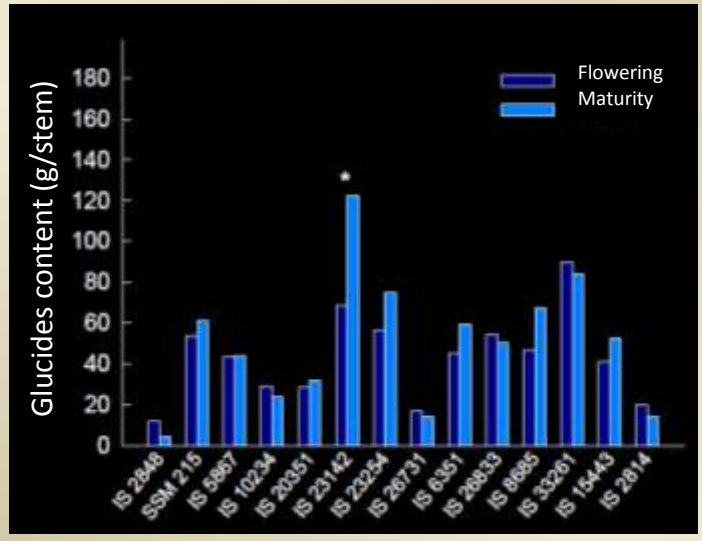


Is there a competition between sugar accumulation and grain production ?

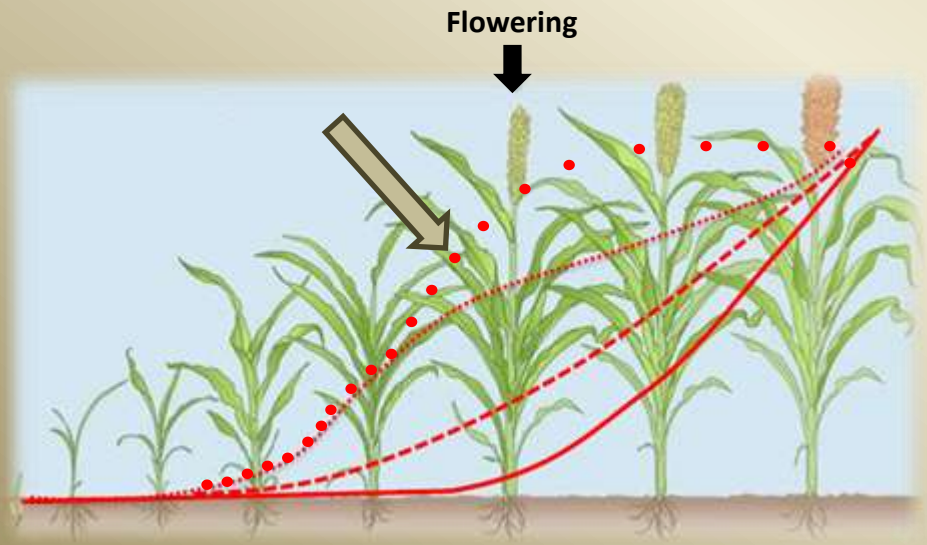
Accumulation of sugar in stalks

(Source: Gutjahr 2012)





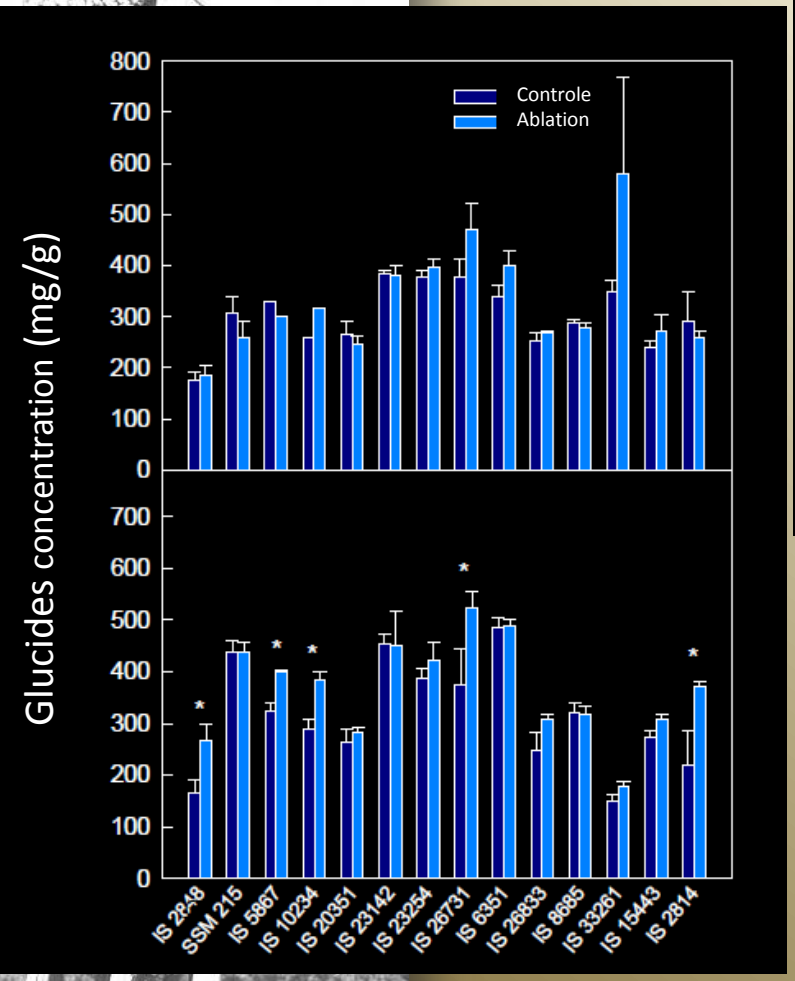
Glucides are accumulated before flowering



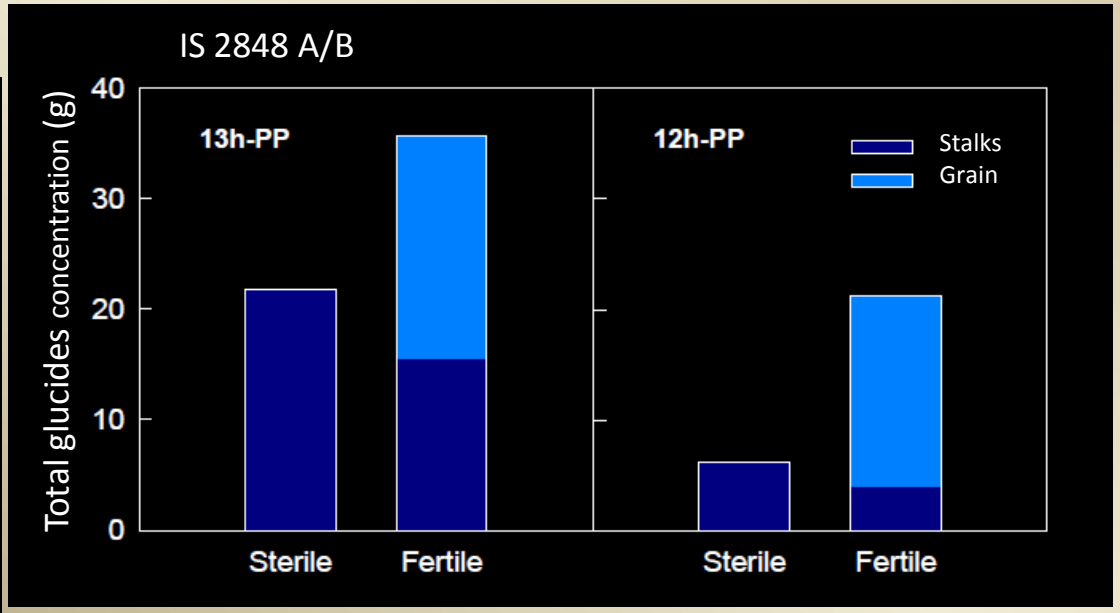
A competition grain/sugar ?

(Source: Gutjahr 2012)

Field experiment



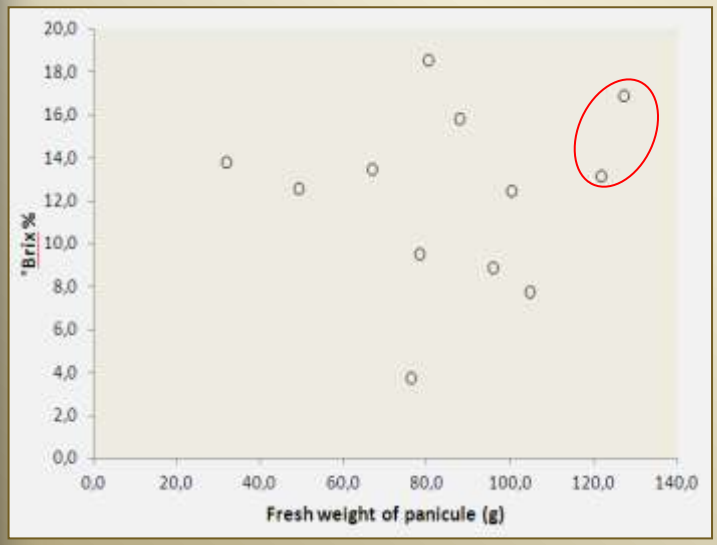
Grennhouse experiment

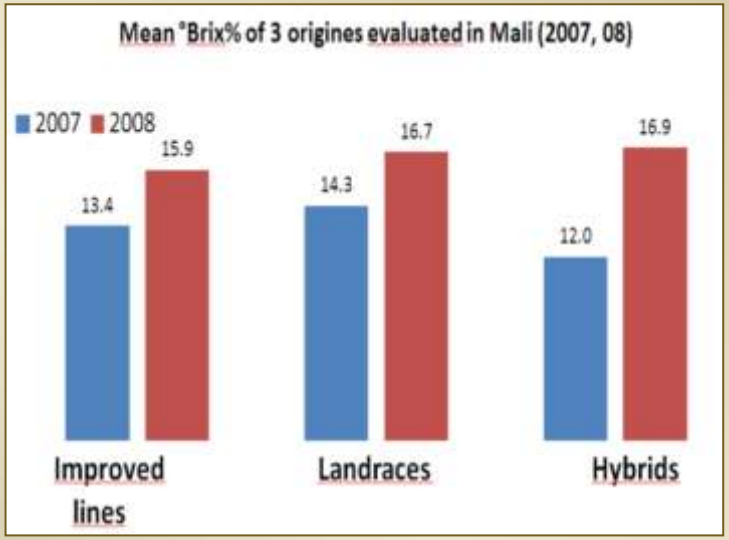


Ablation of panicule has low influence on sugar accumulation.

Competition between sugar accumulation and grain production seems low

Mine the diversity



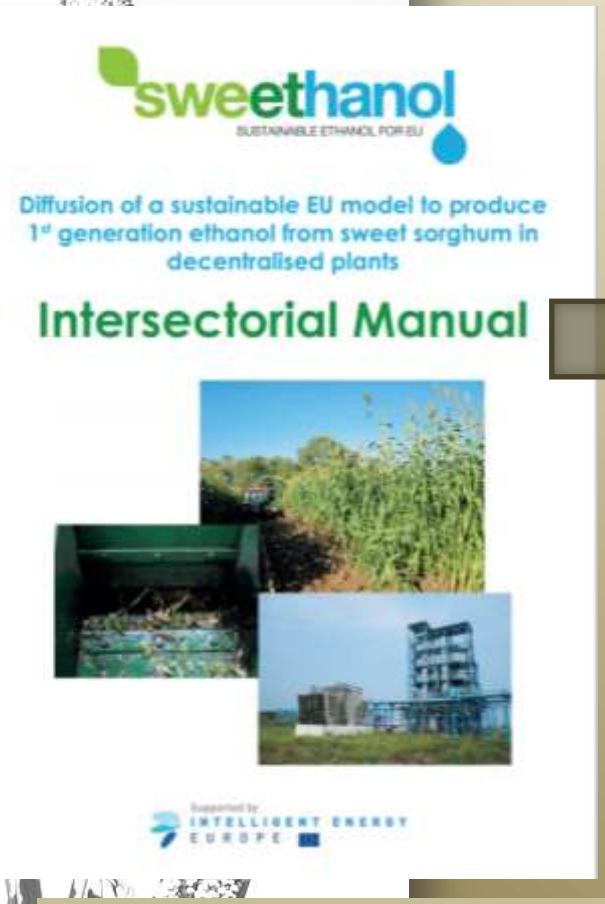


95 T FW + 5 T grain + 7-12% sugar	Almodares et Hatamipour 2011
60 T DW + 4 T grain + °Brix 18	Zhang 2010
20 T DW + 5 T panicule + °Brix% 16 + 12 T juice	Pers. Com. 2011
65 T DW + 2.2 T grain + 18.7 °Brix%	Schaffert 2010
44.8 T FW cane + 4 T grain + 18.4 T juice + 12 °Brix%	S. Rao 2009
…	

There is a competition grain/sugar, but it is low
There is a great diversity in sorghum which must be used without forgeting landraces

"Financial "study…

Source: http://esse-community.eu/wp-content/uploads/2012/02/Sweethanol_Intersectorial_Manual.pdf



Case study in Andalusia (Spain).

Economic analysis			
Costs	Investment cost	30 million €	
	Operative costs	Biomass 29-34 €/t (34 €/t db with a 38% of sugar in the stalk db)	6.23-7.30 million €/year
		O&M	2.69 million €/year
		Other	1.22 million €/year
Incomes	Final products	Bioethanol price 450-800 €/m^3	5.63-10.00 million €/year
		Supported electricity price from biomass 16.81 – 11.38 c€/kWh (10 MWe installed has a production of 86,400 MWh per year, 360 days and 24 h per day)	14.52 – 9.83 million €/year

Table 32: main costs and incomes included in the economic analysis of the case study

Considering the information showed on Table 33, the range of total cost is 10.14-11.21 million €/year and the range of incomes is 15.46 – 24.52 million €/year.

If the total investment cost is fixed on 30 million €, the payback can vary between 2.5 years (the best case) and 7.5 years (the worst case).

These data are quite fantastic !

but let's keep our head cool… and don't create so high expectations that this plant would not be able to meet !!!

…. Remember *Jatropha curcas* !!!

Sweet sorghum has a great potential for producing bio-ethanol but this is not a miraculous plant !

Sweet sorghum: a multiple purpose crop

Food

Feed

Fuel

Fertilizer

Fibers

Bioproducts

...

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Sweet Fuel